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Individual Vs. Group Problem Solving: An Analysis of Processes

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By

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Life

Gary K. Burger was born on December 19, 1938. He graduated from Loyola University with a B.S. in June, 1960. He entered the graduate school of Loyola University in psychology in September, 1960 as a departmental assistant. He became a lecturer in the department of Psychology in June, 1961, which position he has maintained to the present. In May, 1963, he joined the Loyola Psychometric Laboratory as a research assistant. He became a research associate at the Loyola Psychometric Laboratory in December, 1963, and received his M.A. in Psychology in February, 1964. At present he remains a research associate in the Loyola Psychometric Laboratory.

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Problem

The relationship between individual performance and group performance has long been a topic of interest to both sociologists and social psychologists (Bonner, 1959). Experimenters have been interested in defining relationships between individual products and group products and formulating explanations where differences do occur. The purpose of this study is to define and analyze differences between individual and group performance in problem solving and to examine a model which purports to explain these differences.

One of the first important studies in this area was that of Watson (1928). *Ad hoc* groups of college students were given the task of making shorter words from a longer word in a specified time. The subjects first worked as individuals, then groups, and finally individuals. The group product was superior to the individual product in terms of number of words formed. However, when the performances during the individual testing condition were summated, the resulting "concocted group" score was significantly higher than the average *ad hoc* group score. This superiority suggested that the *ad hoc* groups wasted some of the individual's talent and ability even though *ad hoc* groups were superior to the average individual. In a follow-up study, Watson (1929) investigated differences between groups and individuals on nine different tasks. Each task had three equivalent forms. The subjects worked first as individuals, then in *ad hoc* groups, and finally as individuals. While group performance exceeded the average individual performance, an average of one third of the individuals were superior to their groups. In addition, the differences between average individual performance and group performance on some of the tasks were very small and insignificant. The results indicate that differences between group and individual performance are due, to a certain extent, to the nature of the task involved.

Shaw (1932) studied individuals and groups in the rational solution of complex problems. College students were assigned to work as either individuals or groups. Two classes of problems were used - mathematical puzzles ("eureka" type problems) whose solutions were verifiable and problems whose correct answer was arbitrary. The groups again performed better than the individuals. Shaw attributed this to the rejection of incorrect solutions by the groups and also by checks against error. However, many criticisms of Shaw's handling of the data have arisen in the literature (I.e., Marquardt, 1955). Although a significant difference in terms of percentages of correct solution was found, this group superiority rests on only eight solutions by groups in contrast with five by individuals. Marquardt (1955) replicated Shaw's study and obtained essentially the same results. However, Marquardt's method of analysis, which differed from Shaw's, indicated the individual's to be slightly superior to the groups.

Thorndike (1938) advances the hypothesis that as the range of responses increased, the superiority of the group over individuals increased. In four tasks given to college students, the results were in the hypothesized direction. This study supports Watson's argument that the nature of the task is a determinant of group and individual performance.

The above cited studies are classics in this area of experimentation and point out some of the major variables. The type of group studied is an important consideration. Differences between <u>ad hoc</u> and "concocted" groups have already been pointed out. Many other types of groups are also possible (Lorge, 1958). The type of task has been demonstrated as an important variable. Eureka problems and problems with no correct answer (Maier, 1950), as well as other tasks such as judgment (Gordon, 1923), learning (Gurnee, 1937; Zeleny, 1940), memory (Permutter and de Montmollin, 1952) must be distinguished. Finally, group size seems related to the problem (Thomas and Fink, 1963). The dependent variable (s) employed also merit consideration, but this will be discussed later.

This study will focus upon the solution of rational complex problems by <u>ad</u> <u>hoc</u> groups and individuals. In general, subject to the considerations mentioned above, small groups solve problems more quickly and more surely than individuals from the same population (Faust, 1959; Husband, 1940; Lorge, Fox, Davitz, and Brenner, 1958; Lorge and Solomon, 1955; Marquardt, 1955; Shaw, 1932; Taylor and Faust, 1952; Thorndike, 1938; Watson, 1928). However, two points present some difficulty -- the dependent variable used to measure performance and the explanation for differences obtained.

Regarding the first point, Thomas and Fink (1963) point out that four classes of dependent variables are employed: quality of performance, speed, efficiency, and productivity. It is interesting to note that in 1958 Lorge et al. state, "In problem solving, few experimental studies contrast the <u>quality</u> of solutions by groups and individuals."

The quality of group problem solving was studied by Taylor and Faust (1952). In the "twenty questions" game the number of questions asked was employed as a dependent variable. Timmons (1942) used the ranking by experts of solutions to problems with no verifiable answer. Taylor and Faust (1952) also measured time to solution and found groups quicker than individuals. In terms of efficiency (man minutes of labor) individuals are superior to groups. Gibb (1951) and Watson (1928) found productivity (number of correct units produced in a given time period) positively correlated with group size. In summarizing group performance research as a whole, Thomas and Fink (1963) state:

> "...it appears that both quality of performance and group productivity were positively correlated with group size under some conditions, and under no conditions were smaller groups superior. In contrast, measures of speed showed no differences or else favored the smaller groups."

If time or combinations of measures including time are dismissed, only the correct answer, number of questions, and judged quality of performance remains as dependent variables in the problem solving studies cited. This study utilizes the correct answer and number of questions as dependent variables, but in addition, uses the atrategy followed in attempting to solve a problem. That is, not only is the final product used as a dependent variable, but also the process followed in producing this final product.

Dr. H.J.A. Rimoldi has developed both experimental techniques and methods of analysis which he has used to study mental processes in complex problem solving (Rimoldi, 1955; Rimoldi, 1960). The chief assumption made is that problem solving processes cannot be characterized only by the final answer, i.e. a final solution is correct or incorrect. This assumption has been tested in a wide variety of studies (Rimoldi, Devane, 1961; Rimoldi, Haley, Fogliatto, 1962).

To experimentally isolate thought processes from final answers, a particular methodology was developed. Subjects are presented with problems for which they have insufficient information to solve. They are also able to select questions that they want answered in order to acquire the necessary information to solve the problem. The particular questions asked and their sequence is called a tactic. A tactic is considered to be representative of the thought process followed by a particular subject. Thus, both the process and the solution to a particular problem can be experimentally characterized.

A number of procedures have been developed to characterize tactics (Rimoldi, Foggiatto, Erdmann, Donnelly, 1964; Rimoldi, Foggiatto, Haley, Reyes, Erdmann, Zacharia, 1962). These methods are based, in general, upon the comparison of tactics among individuals (group norms) or the comparison of tactics with the logical structure of the problem (schema norms).

Problems may be constructed of varying degrees of logical complexity. The questions available to the subjects can be constructed to fit the logical structure of the problem. Additional questions can be constructed which are extraneous to the structure of the problem. The sequence of questions asked by a particular subject can be evaluated in terms of its approximation to the logical stureture of the problem. This method permits using tactics (evaluated in terms of the structure of the problem) along with the final solution as a dependent variable for studying differences between individuals and groups in complex problem solving. The differences between individuals and groups in terms of cognitive activity then can be specified.

A number of factors have been advanced to explain the superiority of groups over individuals. Shaw (1932) had attributed the superiority of groups to positive personal interaction. Lorge and Solomon (1955) advanced a pooling of ability model which attempts to explain differences between individuals and groups solely by the members' ability, without making recourse to such concepts as "group facilitation" or "interference between group members." The Lorge-Solomon model assumes that group performance in problem solving can be predicted from the performance of individuals alone. No "group effects" need be postulated. Its basic assumption is that when at least one member of a group obtains the correct answer to the problem all other members of the group will adopt the answer. In its most simple form, the model may be expressed as:

$$P_{GC} = 1 - (1 - P_I)^n$$

where

P_{GC} = probability of group arriving at correct answer

P_I = probability of an individual arriving at a correct answer

n = number of people in the group

Thus two parameters, P_I and n are the sole determinants of the success of the group.

A stage model was also developed by Lorge and Solomon to improve the fit of the model with experimental data. This model assumes that several steps or stages must be accomplished before a problem can be solved. The stage model may be expressed as:

$$P_{GC} = (1 - (1 - P_{I1})^n)\ (1 - (1 - P_{I2})^n)\ \ldots\ (1 - (1 - P_{IS})^n)$$

where

P_{GC} = probability that the group solves the problem

P_{I1} = probability of an individual solving a particular stage

S = number of stages

n = number of individuals in the group

The model has been tested (Hoppe, 1962; Davis and Restle, 1962) with mixed results. The principal difficulty is in the estimation of S. Estimates of stages by subjects and a model based upon time to solution have been used (Restle,and Davis, 1963) but no direct estimation of the stages involved in a particular problem has yet been developed.

Dr. Rimoldi's problems provide an experimental definition of the steps or stages hypothesized in the Lorge-Solomon model--the questions that must be asked in order to obtain the correct solution. Since these questions are based upon the logical structure of the problem, their use as a definition of stages seems justified. Thus the asking of the successive questions logically needed to arrive at a solution can be viewed as the progression from stage to stage to the solution of a problem that the model hypothesizes. Measurements can then be taken concerning this progression for both groups and individuals. P_{IS} can be estimated from data obtained from individuals solving problems alone. Thus, P_{I1} would be the probability of an individual asking the first question required for the solution of the problem. P_{GC} can then be estimated and compared with experimentally obtained values from groups.

To summarize, most studies have indicated that groups are superior to individuals in solving rational problems. However, the analysis of this superiority has been chiefly restircted toofinal answers. Dr. Rimoldi's technique, because it focuses upon the process followed in reaching an answer, provides a way of delineating differences occuring in cognitive activity before the final answer is reached. In addition, it provides a means of evaluating one explanation for the differences usually obtained between individuals and groups.

METHOD

Subjects

The subjects were 200 male volunteers from introductory psychology courses at Loyola University. Ten three man, five man, and seven man groups, respectively, and fifty individuals were tested. Individuals were assigned to the various conditions according to their availability for testing at a particular time. Thus, thirty groups and fifty individuals were tested.

Materials

Four problems were utilized - 31A, Telephone, 42, and 50 (in that order). Copies of these problems can be found in the Appendix. Problem 31A was used to acquaint the subjects with the procedure to be followed in solving the problems. The remaining problems were chosen to represent differing degrees of difficulty. Each problem was typed out on a 3" by 5" card. Each question was likewise typed on a card, with the corresponding answer on the reverse side. Each subject tested was given a copy of each problem.

Procedure

All of the subjects (both group and individual conditions) were told that the experimenter was attempting to determine the difficulty level of some problems which he intended to use in future research. This information was intended to be neutral with respect to motivation. Problem 31A was then passes out and termed a practice problem. The subjects were told that they were to solve the problem and the succeeding problems by asking the questions they desired in order to obtain information in order to come to a solution to the problem. The subjects were further instructed to ask as many questions as they wanted, but not more than were necessary to solve the problem.

The groups were, in addition, asked to solve the problems as a group, that is, to work on the problems collectively. The were told that, in order to ask a question, a majority in the group must be in favor of that particular question. In other words, the groups were instructed to vote for the questions which they wished to ask. The method of voting and use of group discussion was left strictly up to the individual groups. Similarly, a majority in the group was required to agree on a final solution before a particular problem could be terminated. The above instructions were the only restrictions placed upon the groups.

Each subject recorded the questions asked, their order, and the final solution. In the group condition dissenting (from the majority of the group) votes for both questions and final solutions were also recorded. While the subjects were working on problem 31A, the experimenter answered questions and made certain that they understood the procedure. The subjects then proceeded to work problems Telephone, 42, and 50.

RESULTS

Besides utilizing the correctness of the final answer, four other dependent variables were employeed - number of questions asked, schema pulling out scores, the relevance ratio, and the appropriateness ratio.

Methods of Scoring Tactics

The number of questions asked is a gross measure of problem solving performance. In general, the fewer questions asked indicates a better grasp of the properties of the problem and efficiency in proceeding from start to finish. It should be remembered, however, that each problem has a minimum number of questions that must be asked in order to reach a correct solution.

Schema pulling out scores are based upon the logical structure of the particular problem involved. The first step involved is the construction of a schema matrix. Ideal sequences of questions, determined by the logical structure of the problem, are enumerated. These sequences are then entered as frequencies in a matrix of questions by order. This table of frequencies is then converted into a table of proportions. This table of proportions is the schema matrix. To determine a schema pulling out score, irrelevant (in terms of the ideal sequence) questions are eliminated from the subject's tactic. The remaining questions are then given values determined by the schema matrix. Finally, this sum is divided by the total number of questions asked. For example, assume a shhema matrix as follows:

Questions

Order		4	5	8
	1	.33		
	2		.33	
	3			.33

Fig. 1

Assuming a subject employs tactic 1, 2, 4, 5, 7 we first eliminate the irrelevant questions asked, leaving the sequence 4, 5. The sequence will get a schema pulling out score of $\frac{.33 + .33}{5}$ or .132. This technique is discussed at length by Erdmann (1964). The schema pulling out method, then, provides an index to the approximation of a subject's tactic to an ideal tactic, as determined by the logic of the problem. The schema matrices, along with the ideal sequences for each problem are found in the Appendix.

The relevance ratio is, along with the problem appropriateness ratio, akin to the schema pulling out method. A relevant question is a question which the subject asks which is in one of the ideal tactics for the problem, irrespective of order. The relevance ratio is simply the number of questions asked which are is a particular ideal sequence divided by the total number of questions asked. This ratio has an upper limit of 1.00. Referring to Figure 1, assume a subject's tactic is 8, 5, 4, 9. The relevance ratio for this sequence would be 3/4 or . 750. This ratio is an index of how a subject's performance approximates not the ideal sequence but the ideal questions, irrespective of sequence.

The appropriateness ratio is identical to the schema pulling out score with the exception that each question in the schema is weighted 1.00 instead of the proportion found in the schema matrix. This is done to equalize the importance of all questions in the ideal sequence (schema). Referring again to Figure 1, a tactic of 1, 2, 4, 5, 7 would yield an appropriateness ratio of $\frac{1.00 + 1.00}{5}$ or .40. This ratio has an upper limit of 1.00. It is an index of how closely a subject's choice of questions and order of choice approximate the ideal sequences or tactics.

The results will be presented in four sections - individuals compared with all with all groups combined, comparison of the different sized groups, comparison of individuals with the different sized groups, and the fit of the Lorge-Solomon model.

Comparison of Individuals with Combined Groups

Tables I through IV present the means, standard deviations, and *t* values of the various performance measures for individuals and combined groups for all four problems administered. The variables contrasted are number of questions, schema pulling out, relevance ratio, and appropriateness ratio. Table V presents the proportion of correct solutions for individuals and combined groups for all the problems along with the X^2 values obtained from comparing individuals to groups with respect to the number of correct solutions.

Comparison of Different Sized Groups

Tables VI through IX present the means and standard deviations of the performance measures of the groups according to group size. Also included are the *F* values obtained from a one way analysis of variance for each problem and each variable. Significant differences between means (utilizing *t* tests) are also indicated. Finally, Table X presents the proportion of solutions for each size group for all four problems, along with the chi square.values.

Comparison of Individuals and Groups of Size 3, 5, and 7

Tables XI through XIV present the means, standard deviations, and *F* values for the performance measures for all four problems considering the various sized groups. All differences between means were tested for those variables where significant *F* ratios emerged ($p < .05$) by a one way analysis of variance. Table XV gives the proportion of correct solutions and chi square values for all of the various sized groups.

TABLE I

Means, Standard Deviations, and t values of Performance Measures for Individuals and Combined Groups for Problem 31A

PROBLEM 31A

	GROUPS (N=30) Mean	S.D.	t	INDIVIDUALS (N=50) Mean	S.D.
Number of questions	3.200	.484	.518	3.289	.835
Schema pulling out	.193	.044	1.731*	.172	.055
Relevance Ratio	.953	.109	1.541	.897	.173
Appropriateness Ratio	.842	.255	1.936*	.705	.314

* = $p < .10$, two tailed test

TABLE II

Means, Standard Deviations, and t values of Performance Measures for Individuals and Combined Groups for Telephone Problem

TELEPHONE PROBLEM

	GROUPS (N=30) Mean	S.D.	t	INDIVIDUALS (N=50) Mean	S.D.
Number of questions	5.967	.890	1.786*	5.342	1.744
Schema pulling out	.089	.048	2.997**	.051	.055
Relevance Ratio	.759	.124	3.827**	.607	.188
Appropriateness Ratio	.462	.265	2.785**	.269	.299

* = $p < .10$, two tailed test

** = $p < .01$, two tailed test

TABLE III

Means, Stmndard Deviations, and t values of Performance
Measures for Individuals and Combined Groups
for Problem 42

PROBLEM 42

	GROUPS (N=30) Mean	S.D.	t	INDIVIDUALS (N=50) Mean	S.D.
Number of Questions	4.233	.626	3.771*	5.368	1.550
Schema pulling out	.233	.067	7.103*	.101	.073
Relevance Ratio	.959	.101	7.151*	.665	.207
Appropriateness Ratio	.891	.267	6.871*	.417	.295

* = p $\angle$.001, two tailed test

TABLE IV

Means, Standard Deviations, and *t* values of Performance Measures for Individuals and Combined Groups for Problem 50

PROBLEM 50					
	GROUPS (N=30)			INDIVIDUALS (N=50)	
	Means	S.D.	*t*	Mean	S.D.
Number of questions	4.567	1.278	2.604**	3.526	1.871
Schema pullingout	.140	.039	1.801*	.1[illegible]8	.059
Relevance Ratio	.659	.169	1.298	.594	.231
Appropriateness Ratio	.621	.182	2.785***	.459	.274

* = $p < .10$, two tailed test

** = $p < .02$, two tailed test

*** = $p < .01$, two tailed test

TABLE V

Proportion of Solutions for all Problems for
Individuals and Combined Groups,
with Chi Square Values

PROBLEM	GROUPS (N=30) Mean solutions	X^2	INDIVIDUALS (N=50) Mean solutions
31A	1.000	8.189**	.76
Telephone	.87	22.90***	.42
42	1.000	8.189**	.76
50	.433	5.011*	.18

* = $p < .05$

** = $p < .01$

*** = $p < .001$

TABLE VI

Means, Standard Deviations, and *F* Values for Performance Measures on Problem 31A for Groups of Size 3, 5,,and 7

PROBLEM 31A

GROUP SIZE

	3		5		7		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	*F*
Number of questions	3.2	.422	3.2	.632	3.2	.422	.000
Schema pulling out	.167	.052	.202	.043	.211	.023	3.256*
Relevance Ratio	.95	.105	.96	.126	.95	.105	.026
Appropriateness Ratio	.683***	.316	.893	.256	.950***	.105	3.575**

* = $p < .10$

** = $p < .05$

*** = Mean Group size 3 differs significantly from Mean Group size 7 at .05 level, two tailed test

TABLE VII

Means, Standard Deviations, and F Values for Performance Measures on the Telephone Problem for Groups of size 3, 5, and 7

TELEPHONE PROBLEM

GROUP SIZE

	3		5		7		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	F
Number of questions	6.5*	.85	5.9	.738	5.5*	.85	3.714*
Schema pulling out	.091	.045	1096	.052	.079	.049	.349
Relevance Ratio	.702	.133	.791	.145	.785	.074	1.666
Appropriateness Ratio	.477	.250	.501	.289	.410	.274	.303

$*$ = $p < .05$

** = Mean group size 3 differs significantly from Mean group size 7 at 105 level (two tailed test).

TABLE VIII

Means, Standard Deviations, and $\underline{F}$ Values for Performance Measures on Problem 42 for Groups of size 3, 5, and 7

PROBLEM 42

GROUP SIZE

	3		5		7		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	$\underline{F}$
Number of questions	4.4	.966	4.2	.422	4.1	.316	.750
Schema pulling out	.214	.078	.210	.084	.245	.016	.825
Relevance Ratio	.937	.143	.960	.084	.980	.063	.437
Appropriateness Ratio	.854	.313	.840	.337	.980	.063	.825

TABLE IX

Means, Standard Deviations, and F Values for Performance Measures on Problem 50 for Groups of size 3, 5, and 7

PROBLEM 50

GROUP SIZE

	3		5		7		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	F
Number of questions	4.7	1.494	4.7	1.337	4.3	1.059	.353
Schema pulling out	.139	.038	.135	.036	.147	.047	.229
Relevance Ratio	.668	.199	.625	.108	.687	.196	.337
Appropriateness Ratio	.601	.188	.608	.138	.653	.226	.231

TABLE X

Proportion of Solutions and Chi Square Values for Groups of size 3, 5, and 7 for the Four Problems

	GROUP SIZE			
PROBLEM	3 Mean	5 Mean	7 Mean	X^2
31A	1.00	1.00	1.00	
Telephone	.8	.9	.9	.234
42	1.00	1.00	1.00	
50	.6	.4	.3	1.899

TABLE XI

Means, Standard Deviations, and $\underline{F}$ Values of Performance Measures for Individuals and Groups of size 3, 5, and 7 for Problem 31A

PROBLEM 31A

GROUP SIZE

	1		3		5		7		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	$\underline{F}$
Number of questions	3.289	.835	3.2	.422	3.2	.632	3.2	.422	.00
Schema pulling out	.172	.055	.167	.052	.202	.043	.211	.023	2.539*
Relevance Ratio	.897	.173	.950	.105	.960	.126	.950	.105	.778
Appropriateness Ratio	.705[a]	.314	.683[b]	.316	.893	.234	.950[ab]	.105	2.946**

* = $p < .10$

** = $p < .05$

a = Mean group size 1 differs significantly from mean group size 7, $p < .05$ (two tailed)

b = Mean group size 3 differs significantly from mean group size 7, $p < .05$ (two tailed)

TABLE XII

Means, Standard Deviations and *F* Values of Performance Measures for Individuals and Groups of Size 3, 5, and 7 for the Telephone Problem

TELEPHONE PROBLEM

GROUP SIZE

	1		3		5		7		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	*F*-
Number of questions	5.34	1.74	6.5	.85	5.9	.738	5.5	.850	1.950
Schema pulling out	.051[a]	.055[a]	.091	.045[a]	.096	.052	.079	.[illegible]9	3.134*
Relevance Ratio	.607[b]	.188	.702	.133	.791[b]	.145	.785[b]	.074	5.487**
Appropriateness Ratio	.269[c]	.299	.477[c]	.250	.501[c]	.289	.410	.274	2.707*

* = p∠.05
** = p∠.01

a = Mean group size 1 differs significantly from both mean group size 3 and 5, p∠.05 (two tailed test)

b = Mean group size 1 differs significantly from both mean group size 5 and 7, p∠.05 (two tailed test)

c = Mean group size 1 differs significantly from both mean group size 3 and 5, p∠.05 (two tailed test)

TABLE XIII

Means, Standard Deviations, and F Values of Performance Measures for Individuals and Groups of Size 3, 5, and 7 for Problem 42

PROBLEM 42

GROUP SIZE

	1		3		5		7		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	F
Number of questions	5.37[a]	1.55	4.4[a]	.966	4.2[a]	.422	4.1[a]	.316	4.625***
Schema pulling out	.101[b]	.073	.214[b]	.078	.210[b]	.084	.245[b]	.016	17.192***
Relevance Ratio	.665[c]	.207	.937[c]	.143	.960[c]	.084	.980[c]	.063	16.716***
Appropriateness Ratio	.417[d]	.295	.854[d]	.313	.840[d].	.337	.980[d]	.063	16.100***

*** = $p < .01$

a, b, c, d, = Mean group size 1 differs significantly with group sizes 3, 5, and 7, $p < .05$ (two tailed test)

TABLE XIV

Means, Standard Deviations, and $\underline{F}$ Values of Performance Measures for Individuals and Groups of Size 3, 5, and 7 for Problem 50

PROBLEM 50

GROUP SIZE

	1		3		5		7		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	$\underline{F}$
Number of questions	3.53	1.87	4.7	1.49	4.7	1.34	4.3	1.06	2.37*
Schema pulling out	.118	.059	.139	.038	.135	.036	.147	.047	1.148
Relevance Ratio	.594	.231	.668	.199	.625	.108	.687	.196	.703
Appropriateness Ratio	.459	.274	.601	.188	.608	.138	.653	.226	2.610**

* = $p < .10$

TABLE XV

Proportion of Solutions and Chi Square Values for all Problems for all Group Sizes

	GROUP SIZE				
PROBLEM	1 Mean	3 Mean	5 Mean	7 Mean	X^2
31A	.76	1.00	1.00	1.00	8.16*
Telephone	.42	.8	.9	.9	14.38**
42	.76	1.00	1.00	1.00	8.16*
50	.18	.6	.4	.3	7.26*

* = p∠.01

** = p∠.001

The Lorge-Solomon Model

The Lorge-Solomon model has two forms, the so-called single stage model and the multi-stage model. The single stage model can be stated as follows:

$$P_{GC} = 1 - (1 - P_I)^n$$

where:

P_{GC} = probability of group solution

P_I = probability of individual solution

n = size of group

Table XVI gives the predicted P_{GC} values for all problems for all sized groups based upon the estimates of P_I obtained from the individuals.

The Lorge-Solomon multi-stage model hypothesizes that problems may have several stages, each with a different individual probability of solution. The multi-stage model can be stated as follows:

$$P_{GC} = (1 - (1 - P_{I1})^n)\ (1 - (1 - P_{I2})^n)\ \ldots\ (1 - (1 - P_{IS})^n)$$

where

P_{GC} = probability of group solution

P_{IS} = probability of individual solution of a particular stage

n = size of group

S = number of stages

Two methods were used to estimate P_{GC} in the multi-stage model. The first method assumed that each question in the schema (ideal tactic) represented a stage of the problem. Thus, the probability that an individual would ask a question in the schema was taken as an estimate of P_{IS}. Tables XVII through XX present the probabilities associated with the asking of each question for each problem as determined by the subjects working alone. The particular questions in each schema sequence can be found in the appendix. Table XXI gives the predicted P_{GC} values based upon this method.

The second method employed to estimate P_{GC} in the multi-stage model is identical to the first, with the addition of multiplying the P_{GC} values obtained above by the P_{GC} values obtained by the single stage model. This procedure assumes that the number of stages in a problem is equal to the number of questions in the schema plus one. That is, the final solution is regarded as the last stage of the problem. The predicted P_{GC} values based on this method is presented in Table XXII.

In order to examine these three sets of predicted P_{GC} values with the observed P_{GC} values, the Kolmogorov-Smirnov one sample test (Massey, 1951) was employed. Tables XXIII through XXV present each set of predictions in terms of the obtained values.

The Kolmogorov-Smirnov test, as can be noted from the tables, rejects the fit of the observed values with the predicted values in Problem 50 for both single-stage and multi-stage models.

TABLE XVI

Lorge-Solomon Single Stage Model

Predicted P_{GC} Values

GROUP SIZE	PROBLEMS 31A	Tel.	42	50
3	.99	.81	.99	.46
5	.99	.93	.99	.64
7	.99	.98	.99	.76

TABLE XVII

Individual Probabilities of Questions Selected for Problem 31A

	QUESTION NUMBER									
	1	2	3	4	5	6	7	8	9	10
P_I	.00	.00	.487	.066	.618	1.00	.00	.039	.697	.461

TABLE XVIII

Individual Probabilities of Questions Selected for the Telephone Problem

	QUESTION NUMBER														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
P_I	.724	.066	.724	.224	.776	.75	.145	.118	.566	.145	.197	.039	.329	.618	.118

TABLE XIX

Individual Probabilities of Questions Selected for Problem 42

	QUESTION NUMBER									
	1	2	3	4	5	6	7	8	9	10
P_I	.934	.539	.987	.566	.829	.197	.224	.829	.197	.197

TABLE XX

Individual Probabilities of Questions Selected for Problem 50

	QUESTION NUMBER									
	1	2	3	4	5	6	7	8	9	10
P_I	.171	.118	.303	.408	.908	.434	.092	.092	.618	.513

TABLE XXI

Lorge-Solomon Multi Stage Model (1)

Predicted P_{GC} Values

GROUP SIZE	PROBLEMS 31A	Tel.	42	50
3	.83	.82	.98	.73
5	.95	.97	.99	.92
7	.98	.99	.99	.97

TABLE XXII

Lorge-Solomon Multi-stage Model (2)

Predicted P_{GC} Values

GROUP SIZE	PROBLEMS 31A	Tel.	42	50
3	.82	.66	.97	.34
5	.94	.90	.98	.59
7	.99	.97	.98	.74

TABLE XXIII

Single Stage Model Predictions, Observed Values, and Differences

	PROBLEMS											
	31A			Telephone			42			50		
GROUP SIZE	Ob.	Pred.	D	Ob.	Pred.	D	Ob.	Pred.	D	Ob.	Pred.	D
3	1.00	.99	.01	.80	.81	.01	1.00	.99	.01	.60	.46	.14
5	1.00	.99	.01	.90	.93	.03	1.00	.99	.01	.40	.64	.24
7	1.00	.99	.01	.90	.98	.08	1.00	.99	.01	.30	.76	.46*

* = P of D < .05

TABLE XXIV

Multi-stage Model (1) Predictions, Observed Values, and Differences

PROBLEMS

GROUP SIZE	31A Ob.	31A Pred.	31A D	Telephone Ob.	Telephone Pred.	Telephone D	42 Ob.	42 Pred.	42 D	50 Ob.	50 Pred.	50 D
3	1.00	.83	.17	.80	.82	.02	1.00	.98	.02	.60	.73	.13
5	1.00	.95	.05	.90	.97	.07	1.00	.99	.01	.40	.92	.52*
7	1.00	.98	.02	.90	.99	.09	1.00	.99	.01	.30	.97	.67*

* = P of D < .01

TABLE XXV

Multi-stage Model (2) Predictions, Observed Values, and Differences

	PROBLEMS											
	31A			Telephone			42			50		
GROUP SIZE	Ob.	Pred/	D	Ob.	Pred.	D	Ob.	Pred.	D	Ob.	Pred.	D
3	1.00	.82	.18	.80	.66	.14	1.00	.97	.03	.60	.34	.26
5	1.00	.94	.06	.90	.90	.00	1.00	.98	.02	.40	.59	.19
7	1.00	.99	.01	.90	.97	.07	1.00	.98	.02	.30	.74	.44*

* = P of D $\angle$ .05

DISCUSSION

Individual vs. Combined Groups

The question of whether groups or individuals are superior in problem solving on these particular problems is rather definitely answered by Tables I through V. The analysis in terms of the total combination of groups was conducted to investigate gross differences between the two conditions, individual and group. The groups consistently manifested a large superiority to the individuals for all performance measures.

In terms of the correctness of final solutions (see Table V), the groups were significantly superior to the individuals for all the problems. Since all of the problems employed have solutions which are highly verifiable (subject to rational demonstration), the results are comparable to other studies using this so called eureka problem as a task (Shaw, 1932; Davis and Restle, 1963). It should also be pointed out that the problems employed evidenced a substantial despersion of difficulty level as defined by the proportion of correct solutions by both groups and individuals. For problems 31A, 42, Telephone, and 50, the proportion of individuals reaching the correct solution were .76, .76, .42, and .18 respectively. The rank order correlation between these values and those of the groups (1.00, 1.00, .87, .43) is +1.00. The difficulty level of the problems employed has left something to be desired in past research. Shaw (1932) used extremely difficult problems having an individual probability of solution of .14, .00, and .09 respectively. David and Restle, (1963) employed problems which were somewhat easier, having probabilities of solution of .73, .50, and .43 respectively. In any case, the results of this study indicate that for eureka-type problems, with levels of difficulty varying very widely, groups generate significantly more correct solutions than do individuals.

Differences in the tactics employed by groups and individuals are also clearly evidenced (see Tables I through IV). Mean group performance differs significantly from mean individual performance on all the problems for schema pulling out, the relevance ratio, and the appropriateness ratio. This means that under all three methods of estimating the approximation of observed tactics to logically defined ideal tactics, the groups are clearly and significantly superior to the individuals. In the sequence of questions chosen in order to reach a final solution to the problems, groups, irregardless of difficulty level of the problem, utilize tactics which are more logical than those employed by individuals. Groups are able not only to arrive at more correct answers than individuals, but also proceed to do so in a more logical manner. These differences had been previously unspecified in experimental studies.

The number of questions asked, as a dependent variable, is somewhat more difficult to interpret. On two of the problems (50 and Telephone) the groups asked more questions than the individuals ($p < .10$ and $.02$ respectively) while on problems 31A and 42, the groups asked fewer questions ($p < .001$ for problem 42). This differs from the findings of Taylor and Faust (1952). This disagreement may be a function of the type of problem employed. One possible explanation is that for the relatively easy problems, groups proceed directly and more logically to the correct solutions than do individuals. However, for more difficult problems groups ask more questions because they regognize and correct false approaches to the problem. This recognition and restructuring does not occur to as great a degree in the case of the individuals, as evidenced by the lower scores their tactics received. Since, in each of the measures for the tactics, the denomimator is always the number of questions asked, the groups obtained their higher mean score for tactics by returning to the more logical sequence of questions more often than the individuals did. The above interpretation can be regarded as an extension of some ideas advanced by Thorndike (1938). Thorndike maintained that as the number of alternative responses increased, the superiority of groups over individuals became more pronounced. In addition, he suggested that elimination of individual errors occured in group situations, As indicated by the data of this study, groups are better able to restructure their approach - change their tactics - when it is realized they are in error. This would also imply that groups are more likely to recognize such errors when they occur. Finally, it is indicated that the need for restructuring is present to a much greater degree in difficult problems than in more easy ones.

Effects of Group Size

Tables VI through X present the results of an analysis of the effects of group size upon tactics and final aolutions. Here the effects present no clear pattern, which represents a substantial agreement with the literature in this area.

In terms of correct final solutions (see Table X) no significant differences emerged. For problems 51A and 42 all groups arrived at the correct solutions. For the more difficult problems (based upon performance in the individual condition) opposite relationships emerged. Group proportion of correct solutions for the Telephone problem were .8, .9, and .9 for groups of sizes 3, 5, and 7 respectively. However, for Problem 50, the proportions were .6, .4, and .3 respectively - a negative relationship between group size and correct solutions. This suggests the possibility that, for difficult problems group size may have a negative influence upon correct solutions. The lack of significance between the proportion of correct answers for the various sized groups disagrees with the findings of Taylor and Faust (1952). However, this lack of difference agrees with the findings of Lorge and Solomon (1959, 1960), where no relationship was found between group size and correctness of the final answer. In addition, for groups of size seven, there was a decrease in the proportion of correct solutions for a eureka-type problem.

The various measures of tactics (schema pulling out, relevance ratio, and appropriateness ratio) yielded a significant $\underline{F}$ ratio solely on problem 31A for the appropriateness ratio. The mean of the three man groups differed significantly from the mean of the sevdn man groups. Problem 31A indicates a positive relationship between excellence of tactics and group size. On the Telephone problem, the relationship appears to be curvilinear, with seven man groups evidencing a decreasing level of tactical excellence. Problems 42 and 50 indicate in general a slight decrease at size of group = 5 followed by an increase for thesseven man groups. However, as has been stated, these differences are not significaat. The existence of curvilinear relationships existing between quality of performance and group size has been found by Ziller (1957), although the task was a judgemental one and not problem solving.

The number of questions asked remained the same or decreased as a function of group size on all four problems. However, only the Telephone problem yielded a significant $\underline{F}$ value, with the mean of the three man groups being significantly larger than the seven man groups. These findings agree with those of Taylor and Faust (1952).

Individuals vs. Three, Five, and Seven Man Groups

After the analysis of gross differences between individuals and groups add the specific examination of differences solely withinggroups, an analysis considering individuals and the three different sized groups simultaneously was undertaken (see Tables XI through XV).

Considering the dimension of group size (with individuals being a "group" of one), significant chi square values for the number of correct solutions were obtained for all problems. As has been noted earlier, the differences were in the expected direction for all problems except 50. Despite the relatively poor performances by the five and seven man groups, they were still superior to the individual condition. The results obtained in problem 50 are strikingly paralell to results obtained on the so-called Tartaglia problem (Lorge and Solomon, 1960), the precise values for solutions by individuals, groups of four, and groups of seven being .16, .66, and .46 respectively.

As can be seen in Tables XI through XIV, the inclusion of individuals and differenct sized groups in the analysis of variance demonstrates that while individuals may differ significantly from groups as a whole, this difference does not necessarily extend to particular sizes of groups. However, with the exception of problem 31A (which was utilized as a practice problem), in no case did the evaluation of individual tactics in terms of ideal sequences equal or exceed the evaluation for a particular sized group.

Referring to the evaluation of the tactics, problem 50 yielded no significant overall differences, while the other three problems did. With the exception of the appropriateness ratio on problem 31A, all of these significant differences were between the individuals and various sized groups. All these significant differences were in the expected direction, with the groups having better scores than the individuals. On problem 42, all of the groups were significantly better than the individuals for the three measures of excellence of tactics. While specific differences are not always significant, groups of sizes three, five, and seven, respectively, not only have a higher proportion of correct solutions for the problems than individuals, but also approximate logically defined ideal tactics more closely in the process of trying to arrive at a solution. The pattern represented is remarkably clear.

The number of questions asked again presented a clear pattern. For the Telephone problem and problem 50 the individuals asked fewer questions than each of the groups. Exactly the opposite pattern emerged on problems 31A and 42, with problem 42 showing significant differences.

Considering the data concerning correct solutions and processes as a whole, several factors clearly emerge. With respect to final solutions, groups are clearly superior to individuals. Within groups of various sizes, the relationship between group size and correctness of final solution has not been significantly demonstrated. In fact, for some problems (more difficult ones) the relationship may be negative. Groups also proceed significantly more logically in their attempts to reach the final solution. This superiority is present in groups of all three sizes tested. Process, as a variable preceeding products, is also an important difference between individuals and groups. The superiority of groups over individuals in terms of correct answers may be due to the superior ability of the group to logically structure <u>and</u> restructure its tactic. This has not been experimentally demonstrated heretofore. It is suggested that, in the future, a number of different possibilities may be explored. Groups of different sizes along with problems of different logical structures may be employed. Additional independent variables can be introduced (i.e. motivation) and measures of social interaction obtained. In this manner, influences upon the groups' structuring and restructuring processes could be assessed.

<u>The Lorge-Solomon Model</u>

The Lorge-Solomon model represents an attempt to explain group superiority by a pooling of abilities model. The predictions of its two forms (one form determined by two methods) and the observed values are contained in Tables XVI through XXII. The tests of goodness of fit of the various models are given in Tables XXIII through XXV.

First of all, some general comments are in order. This study represents the first time this model has been investigated utilizing problems covering a full range of difficulty levels. Previous investigators (Lorge and Solomon, 1955; Lorge and Solomon, 1959; Restle and Davis, 1963) have typically used fairly easy or fairly difficult problems. The multi-stage model has never been directly tested, although Restle and Davis (1963) used a model based on time to solution to estimate the number of stages in a problem. The experimental definition of S as employed in this study is unique.

The Kolmogorov-Smirnov test, which was employed as a measure of goodness of fit, is a non-parametric test. If D (the largest difference between predicted and observed values) is sufficiently large, the observed values cannot be considered to be random or chance departures from the predicted values. It should also be remembered that for most tests of goddness of fit, a given set of observed values may "fit" a number of predicted distributions.

The observed proportions fit both the single stage model and the multi-stage model (both methods of determination) for problems 31A, 42, and the Telephone problem. Even if the level of significance had been set at $p = .20$ (which is as high as publßshed tables go for this test) none of the models could have been rejected for the first three problems. However, both the single stage and multi-stage models are rejected for problem 50. There are a number of possible reasons why this should occur. It is possible that as higher values of n are reached the relationship implied by the model does not hold. The model (S) is not rejected for $n = 3$ and is only rejected at $n = 5$ for multi-stage model one. It is also possible that problem 50 is not, strictly speaking, a eureka-type problem. However, this possiblity is allayed by the correspondence of problem 50 (in terms of P_I and observed P_{GC}) to the Tartaglia problem described by Lorge and Solomon (1960) as a eureka-type problem.

The single stage and multi-stage models closely approximate each other as n becomes larger and as P_I and P_{IS} become larger. As this happens P_{GC} rapidly approaches a value of 1.00, making predicted P_{GC} values indistinguishable from one model to another. The one problem (50) which more rigidly tests both models was foudd to be incompatible with them. The above results cast doubt over the applicability of the Lorge-Solomon models over wide ranges of both n and P_I. Partial support for both models, however, is obtained from problems 31A, 42, and the Telephone problem. In view of the mixed results in the literature (Hoppe, 1962; Davis and Restle, 1963) the deficiencies suggested by this study should be given some attention.

SUMMARY

Many empirical investigations have compared problem solving in groups with individuals, with groups ordinarily proving to be superior with respect to the number of correct solutions. While this superiority has been demonstrated frequently, the quality of behavior before solution has yet to be investigated. Dr. H.J.A. Rimoldi has originated a technique designed to study (on an individual level to the present) processes occuring between the presentation of a problem and the advancement of a final solution, an area often ignored in traditional investigations. Rimoldi's technique involves the study and analysis of both the order and questions asked by subjects in attempting to solve problems. The sequence of questions asked is called a tactic. Several methods have been developed to compare the approximation of subject's tactics to certain logically defined ideal sequences. These methods were employed to define diffesences between group and individual problem solving. In addition, a pooling of abilities model (Lorge and Solomon, 1955) was also investigated as a possible explanation for group superiority in terms of final solutions. The Rimoldi technique permitted the examination of a portion of the model which had previously not been experimentally tested.

A total of two hundred male undergraduate introductory psychology students at Loyola University were utilized as subjects. Ten seven man, five man, and three man groups respectively, were tested, along with fifty individuals. The subjects were administered four problems - 31A, Telephone, 42, and 50 (in that order) - under neutral motivational conditions. Tactics were scored according to four methods measuring their approximation to ideal sequences.

In terms of correct solutions, the groups proved superior to the individuals on all the problems. Logically evaluated in terms of tactics, the groups again were significantly superior to the individuals on all problems. It was suggested that, for more difficult problems, groups were better able to restructure their tactics than individuals.

No significant differences were noted among the various sized groups on correct answers or tactics. In comparing the individuals with the various sized groups, it was noted that the performance of individuals (considering both final solutions and tactics) at no time equalled or exceeded the performance of the various sized groups, although not all the differences obtained were significant. In general, positive linear relationships did not always exist between group size and performance.

The data for the groups (correct solutions) were found to fit both the single stage and multi-stage Lorge-Solomon models for the first three problems. The last problem (50) did not fit any of the versions of the model. Limitations of the Lorge-Solomon model in terms of N and difficulty level of the problem were pointed out.

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Appendix

Problem 31A

Instructions and Corresponding Questions and Answers.

At Spencer High School the annual fall dance is about to be held. A dance committee has been selected to make the necessary arrangements. Both boys and girls are on the committee. A part of the committee is to take care of the refreshments for the evening and another part will look after the sale of the tickets for the dance. The list of the girls on the dance committee involved in the sale of tickets has been lost. From the other information available, which you will find in the questions, your object will be to discover the number of girls involved in the sale of tickets.

Questions	Answers
1. Is Spencer High School the only coeducational school in the city?	1. No
2. How many boys attend Spencer High?	2. 240 boys attend Spencer High
3. How many boys are on the dance committee?	3. 10 (ten)
4. Are there more girls than boys at this school?	4. Yes
5. How many students on the dance committee are assigned to supplying the refresh- men ments?	5. 14
6. What is the total number of students on the fall dance committee?	6. 25
7. How much time would the committee as a whole spend in preparation for the dance?	7. 275 hours
8. How much time would the averate committee member contribute?	8. 11 hours
9. How many boys on the committee are involved in the sale of tickets?	9. 6 boys
10. How many girls are on the refreshment part of the dance committee?	10. 10 girls

Problem 31A

Ideal Sequences

1) 6, 5, 9

2) 6, 3, 10

ORDER		3	5	6	9	10
	1			.333		
	2	.166	.166			
	3				.166	.166

Answer = 5

Telephone Problem

Instructions and Corresponding Questions add Answers

At a textile factory in a small town the telephone system connecting the various factory offices is rather primitive. However, communications between offices is greatly aided by the netwoek, since the offices are considerably separated.

Basically the factory has a north wing comprising offices A, B, and C, and a south wing in which are officed D, E, F, G, and H. At the time the phones were installed only seven were available and consequently office G is without one. Because of the way in which the phones have been wired certain limitations are these: 1) There is not a single phone from which all the other offices with phones may be callyd, 2) The fact that one office can call another does not necessarily mean that the last office can call the first. With this present confusion in the telephone network a worker in office B would like to contact someone in Office H. What is the most efficient way in which this can be accomplished?

Questions	Answers
1. Is there a line from any office in the north wing to H?	1. No
2. Which office can issue outgoing calls to the greatest number of other offices?	2. Office E
3. What offices can office C call?	3. Offices D and E
4. Can office A call office H?	4, No
5. From which offices in the south wing can office H receive calls?	5. Only from office D
6. What offices in the north wing can call offices in the south wing?	6. Only office C
7. Can every office in the north wing call every office in the south wing?	7. No
8. Can office B.call office A?	8. Yes
9. What officesiin the north wing can call office C?	9. Only office B
10. Can office C call office B?	10. No
11. What offices can office H.call?	11. None
12. Can every office in the south wing call every office in the north wing?	12. No
13. What offices can office E call?	13. Offices A, B, C, D, F
14. Can office B call office H?	14. No
15. Can any office in the south wing call any office in the north wing?	15. Yes, only Office E

Telephone Problem

Ideal Sequence

1) 14, 1, 5, 6, 9,

2) 14, 1, 5, 3, 9

ORDER	1	3	5	6	9	14
1						.20
2	.20					
3			.20			
4		.10		.10		
5					.20	

Answer = B-C-D-14

Problem 42

Instructions and Corresponding Questions and Answers

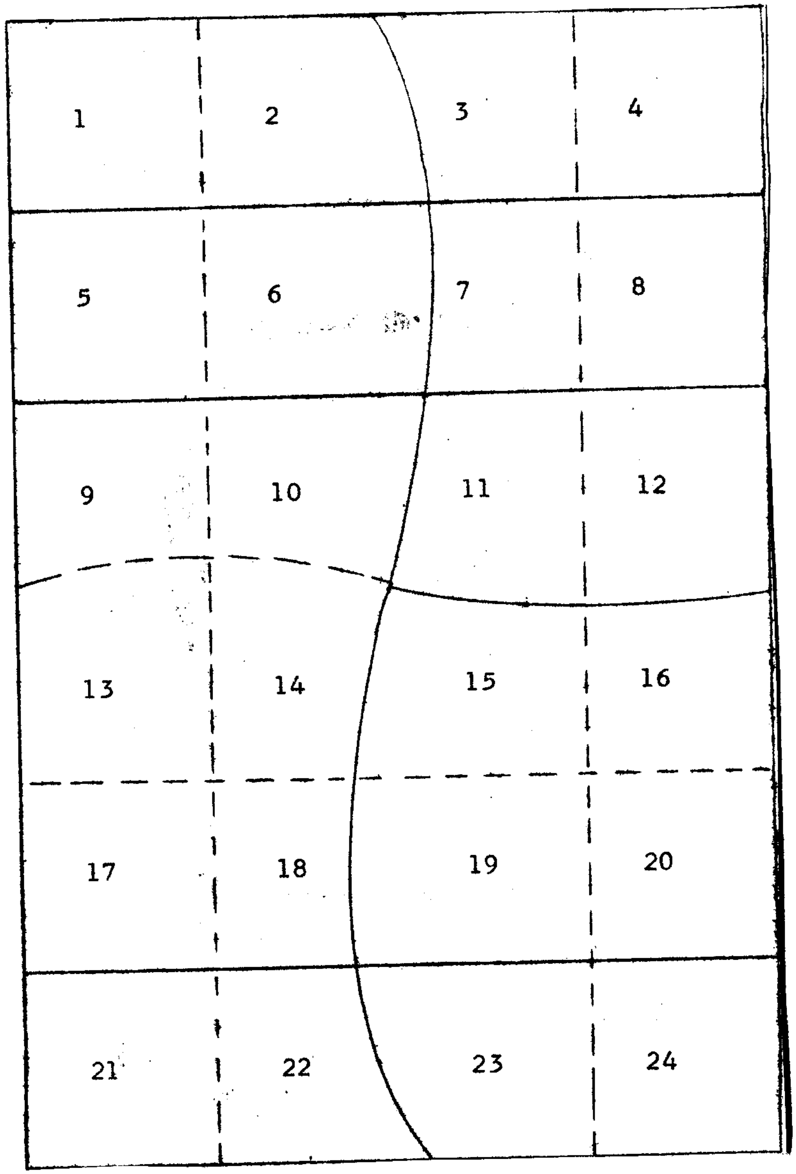
This figure is composed of 24 areas. The numbers in the areas are merely for the purpose of identifying a particular area and have no bearing on the solutions of the problem whatsoever.

One of the areaa has been selected. Your task is to discover the selected area. You may discover this area by using any of the questions you like to arrive at the answer.

Proceed by reading over all the questions. Decide upon the first questionsyou would like to have answered and write its number on the page provided. Then, read the answer on the back of the card. After having read the answer, decide upon the next question you would like to have answered, write down its number and read the answer. When you are satisfied that you have arrived at the answer, stop asking questions and write down your answer. Remember, you may ask as many questions as you need to find the correct area, but do not ask more questions than you need.

Questions	Answers
1. Is it above the unbroken curve line?	1. No
2. Does it have 2 curved lines as borders?	2. No
3. Is it to the right of the vertical curve line?	3. Yes
4. Does it have 2 continuous straight lines and 2 broken lines as borders?	4. No
5. Does it have 2 broken straight lines borders?	5. No
6. Does it have any combination of 2 broken and 2 curved sides?	6. No
7. It it below the dotted curve line?	7. No
8. Does it have 3 continuous straight lines and 1 broken straight line as borders?	8. No
9. Does it have a broken curved line as a border?	9. No
10. Does it have at least 1 continuous straight line and 2 continuous lines as borders?	10. No

Problem 42



Problem 42

Ideal Sequence

3, 1, 5, 8

ORDER		1	3	5	8
	1		.25		
	2	.25			
	3			.25	
	4				.25

Answer = 23

Problem 50

Instructions and Corresponding Questions and Answers

Assume that X, A, D, P, and S, represent properties among F objects. Not-X, not-A, and so on, represent lack of these properties. Out of F.objects some of them are X's, and some not-X's. The not-X's are formed by not-A's and not-D's. A not-A can not be a not-D and vice versa.

Some of the not-X's also are not-P's, and some others are not-S's. A not-P can not be a not-S and vice versa.

How many not-D's are also not-S's?

Questions	Answers
1. Are there not-X's that are A's and D's?	1. No
2. How many not-A's are F's?	2. 100
3. Are there more not-D's than not A's among the F's?	3. Yes
4. How many not-A's are not-X's?	4. 14
5. What is the total number of not-X's?	5. 40
6. How many not-X's are not-P's?	6. 24
7. What is the value of 1 times the not-X's?	7. 440
8. What is the value of 1?	8. 11
9. How many not-D's that are not-X's are also not-P's?	9. 20
10. How many not-A's that are not-X's are also not-S's?	10. 10

Problem 50

Ideal Sequence

1) 5, 6, 10

2) 5, 4, 9

ORDER	4	5	6	9	10
1		.333			
2	.166		.166		
3				.166	.166

Answer = 6

Approval Sheet

The dissertation submitted by Gary K. Burger has been read and approved by a board of five members of the Department of Psychology.

The final copies have been examined by the director of the dissertation and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the dissertation is now given final approval with reference to content, form, and mechanical accuracy.

The dissertation is therefore accepted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.

Aug 26/66
Date

Signature ~~of~~ Advisor